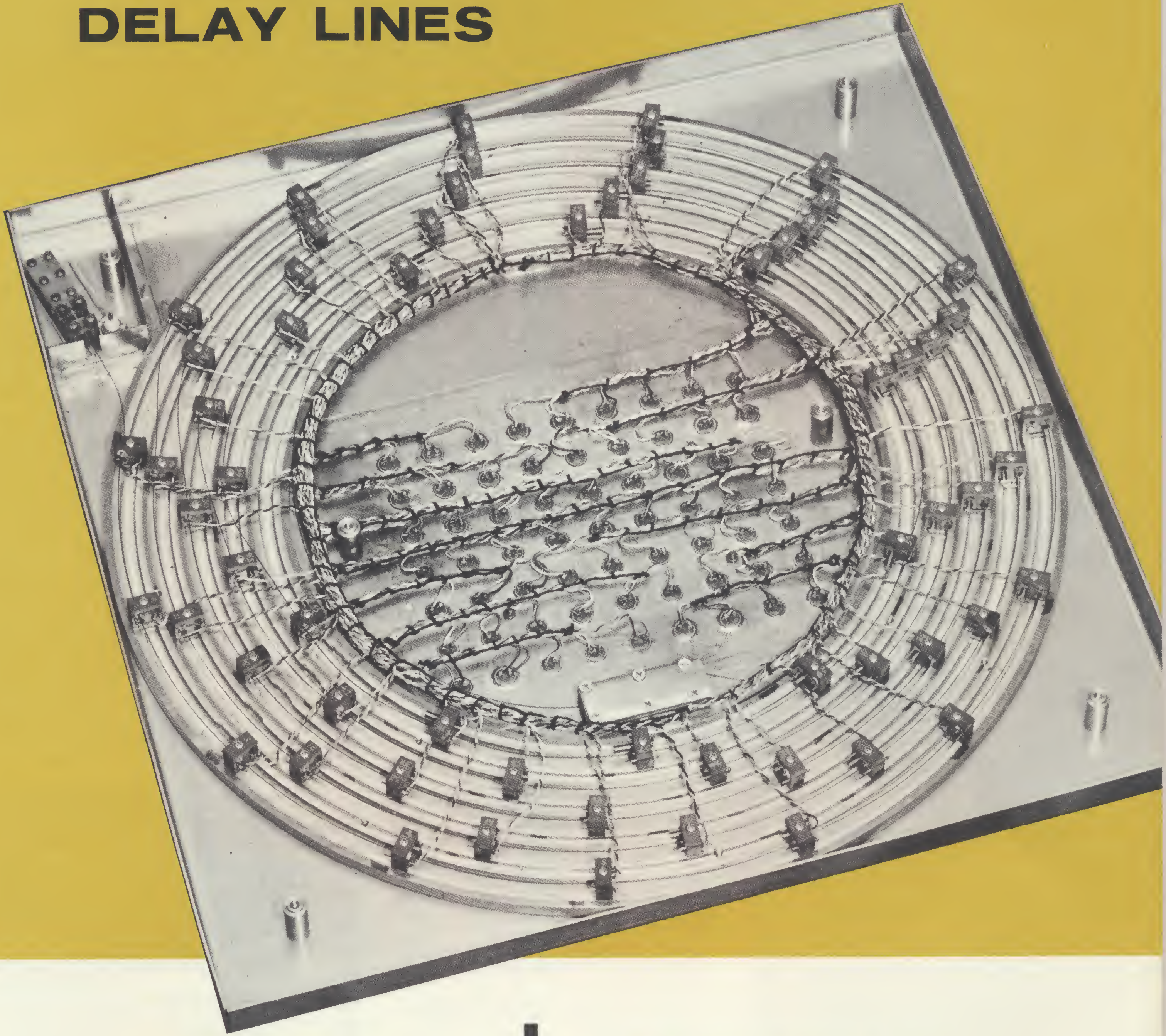
GENERAL ELECTRIC

WIRE SONIC DELAY LINES



FEATURING

Low Cost per bit of Storage
Low power dissipation
High reliability
Stable over wide temperature range
Low volume and weight

APPLICATIONS IN

Computer Data Storage
Signal Processing
Pulse Timing
Integration & Correlation

GENERAL ELECTRIC
SPECIALTY DEVICES OPERATION
SYRACUSE, NEW YORK

Leadership – by design

The leadership in wire sonic delay lines by General Electric's Specialty Devices Operation is the result of its people, facilities and purpose. SDO is organized to develope, design, manufacture and market advanced electronic devices to commercial and military users.

As you will notice in this brochure, we offer you the industry's largest selection of standard and custom designed wire sonic delay lines, longitudinal and torsional, magnetostrictive and piezoelectric transducers. With the increasing acceptance of delay lines by engineers to be used as the storage element in digital systems and in signal processing applications, *SDO offers designers a further service for complete memory packages, including all circuitry in encapsulated or printed wiring form.*

The Wire Sonic Delay Line can be used wherever large delay-bandwidth products are required or temperature stability is of major importance. G.E. has had the opportunity to supply design engineers this advance type of delay line for computer data storage, signal processing, integrating circuits and pulse timing, in addition to classified projects.

We invite you to use the convenient questionnaire which is enclosed. It has been designed to aid you in your delay line requirement. If you desire additional copies, do not hesitate to request them — we'll send them to you immediately.

The principle of the wire sonic delay line is to convert an electrical pulse traveling at near the speed of light into an acoustical wave traveling approximately 100,000 times slower, and then to convert it back into an electrical pulse. There are basically two means presently employed to perform these transformations; the Magnetostrictive and the Piezoelectric Transducers. Within these two types of wire sonic delay lines, a further difference is available, the longitudinal mode and the torsional mode. For your evaluation, a description of each follows.

MAGNETOSTRICTIVE
— Longitudinal Mode

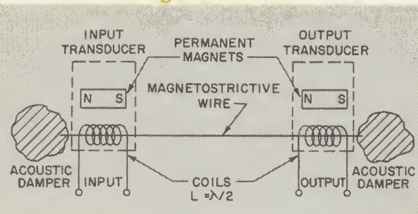


Fig. 1

Makes use of longitudinal sound waves. The particle motion is in the same direction as wave motion. Useful in low to medium storage applications — readily tapped.

Because of magnetostrictive principles, an input current pulse increases the flux in the coil, causing it to expand or contract, depending on the material. A permanent biasing magnet is employed in a linear region of the hysteresis loop. The sonic wave travels from the magnetostrictive transducer in both directions at approximately 5.4 usec./inch. The damping material absorbs the wave in one direction, while the other direction leads through the output coil before being absorbed in the dampening material on the other end. As this acoustical wave passes through the output coil, also pre-biased, it changes the flux field and establishes an electrical pulse by means of the Villari effect, because of the applied stress. The output pulse has been delayed approximately 5.4 usec/inch of wire between the two coils, if the wire be nickel or nickel-iron alloy.

MAGNETOSTRICTIVE
— Torsional Mode

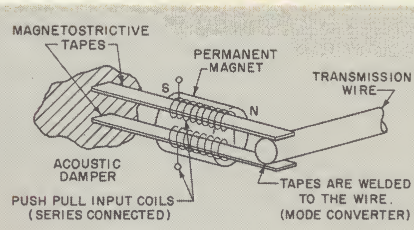


Fig. 2

Torsion (shear) waves travel with negligible distortion and require approximately 40% less wire for a given delay. Useful for large capacity storage and applications requiring large delay bandwidth products.

In this transducer, one coil applies an opposing flux to the applied field while the other applies an additive flux to the applied field. This establishes two longitudinal waves 180° out of phase in respect to each other, i.e. — one wave is an expansion and the other a contraction. As these two waves propagate down the longitudinal members, they are coincident at the welds and thus apply a twist to the wire. This twist establishes a torsional wave in the wire which is transmitted to the opposite end, where identical transducers convert the torsional wave into two longitudinal waves which in turn establish an electrical output pulse. This welded combination of tape and wire is designated as a mode converter.

The non-dispersive feature would indicate the line could be made for any length delay. The transmission wire does, however, have certain band pass characteristics which limit the practical length of obtainable delay.

MAGNETOSTRICTIVE
Longitudinal

Maximum Frequency	1.5 Mc (RZ) 3.0 Mc (NRZ)
Maximum Delay	20 M sec
Minimum Delay	1μ sec
Signal-to-Noise Ratio	
Static (single pulse) max.	50:1
Dynamic (signal pattern) max.	30:1
Insertion Loss:	
Transducer Losses (each transducer)	18-25 db.
Losses in Delay Medium	1-2 db/M sec
Support Losses	Dependent on delay line geometry.
Delay Tolerance @ 25°C (fixed outputs & fixed taps)	±0.1 μ sec
Taps Available	Yes
Characteristic Impedance (Frequency Dependent)	200-1500 ohms
Temperature Coefficient of Delay (min.)	1-2 ppm/°C
Dynamic Range of Input	20 db.
Vibration (Operating)	20 G's (20-2000 cps)
Shock (Operating)	50 G's (11 M sec)
Temperature Operating Range (max.)	—55 to +100C

MAGNETOSTRICTIVE
Torsional (Mode Converters)

Maximum Frequency	1.2 Mc (RZ) 2.4 Mc (NRZ)
Maximum Delay	20 M sec
Minimum Delay	20 μ sec
Signal-to-Noise Ratio	
Static (single pulse) max.	30:1
Dynamic (signal pattern) max.	10:1
Insertion Loss:	
Transducer Losses (each transducer)	18-25 db.
Losses in Delay Medium	1-2 db/M sec
Support Losses	Dependent on delay line geometry.
Delay Tolerance @ 25°C (fixed outputs & fixed taps)	±0.1 μ sec
Taps Available	Only at ends of delay line
Characteristic Impedance (Frequency Dependent)	200-1500 ohms
Temperature Coefficient of Delay (min.)	1-2 ppm/°C
Dynamic Range of Input	20 db.
Vibration (Operating)	20 G's (20-2000 cps)
Shock (Operating)	100 G's (11 M sec)
Temperature Operating Range (max.)	—55 to +100C

for WIRE SONIC DELAY LINES

RZ CLOCKING AND DETECTION TECHNIQUES — The delayed output occurs during the down time period between two strobe clock pulses. This delayed output is peak detected and then its leading edge sets the FF. The "1" output of the FF, at a later time, ANDs with the strobe clock, enables the OR gate, then ANDs with the clock. The clock pulse is inverted, the leading edge resets flip flop and at the same time is inverted again and fed back to the OR gate, thus locking the two output inverters onto the clock pulse.

WRITE-READ AMPLIFIERS — The write amplifier, besides amplifying the incoming signal, provides a suitable driving impedance for the wire sonic delay line.

A buffer stage is usually provided on the output in order that each delay line can be tuned for optimum operation. The read amplifier is a Class A wide band amplifier which amplifies the low level output signal to amplitude sufficient for detection.

The signal may be threshold or peak detected. Threshold detection is of course, the simplest. Peak detection can be accomplished by either a capactively or inductively coupled circuit.

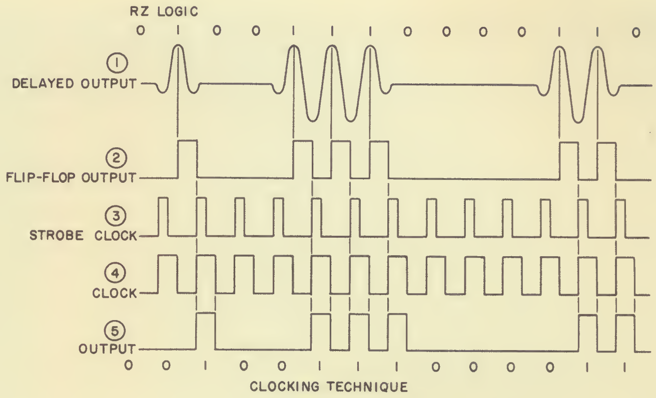


Fig. 9

NRZ CLOCKING AND DETECTION TECHNIQUE — It will be noted that variation of delay is inherent in threshold detection technique, due to amplitude variation. In NRZ recording, a double amplitude is obtained for a 001000 combination as illustrated. Variations in threshold levels also contribute to a change in delay.

The flip-flop detector is set and re-set by the delay signal, thus shaping it back to its original waveform. The timing flip flop contains two input AND gates which synchronize the detected signal to the clock. Thus the circuitry delays (stores) the incoming signal, reshapes it, and synchronizes it to the clock.

The input transition rise and fall times should be as nearly identical as possible in order to have symetric output pulses. Faster switching times in respect to the frequency response of the line make the need for the rise and fall times being identical less critical. Normally, the transient times are within the upper limit of the cutoff frequency of the line for optimum electrical matching.

Due to the fact that the magnetostrictive impedance is inductive, the switching speed is basically an L/R time constant. Thus for fast switching speeds, a current source (high resistance) is desirable.

The time constants of interest in the piezoelectric transducer is the RC time constant, which means R is to be sufficiently small enough to provide adequate switching speeds.

WRITE-READ AMPLIFIERS — The write-read amplifiers described for the RZ technique are suitable for NRZ.

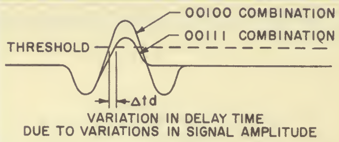


Fig. 10

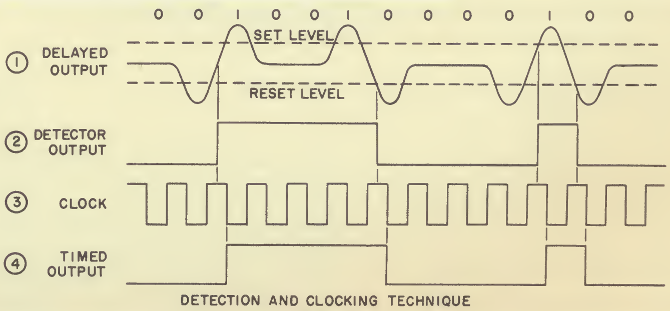


Fig. 11

BIPOLAR CLOCKING AND DETECTION TECHNIQUE — In order to detect this output signal, it is necessary to strobe the signal pulse. When strobing, it is necessary that the strobe pulse be coincident with and of the same polarity as the "1" for an output, and of opposite polarity with the "0" in order to inhibit the output. It will be noted that it is necessary to detect as nearly as possible to the AC base line of the signal waveform for the optimum timing tolerances.

WRITE AND READ AMPLIFIERS **(see page 7)**

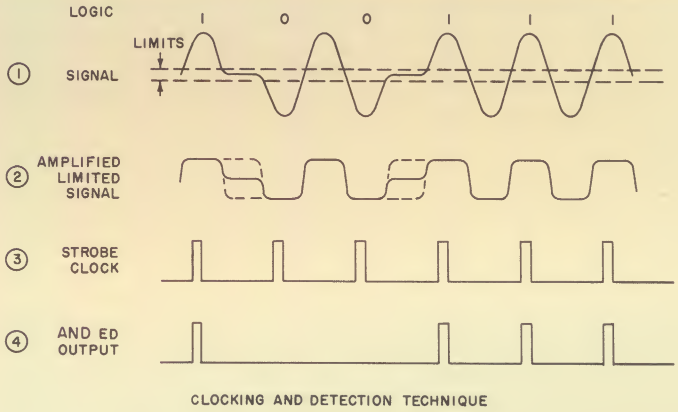


Fig. 12

ments to simplify techniques of manipulating or modifying information signals.

The signals may be either of the straight carrier, burst or modulated carrier types. Center frequency should preferably be between 200 and 500 kilocycles, although it is frequently possible to accommodate higher or lower frequencies, depending on other delay line requirements.

These delay lines are usually tuned to a specific carrier frequency, particularly in the case of those designed for less than 100% bandwidth. Tuning of these narrow band lines greatly reduces the voltage insertion loss, thereby simplifying associated circuitry.

Many of the carrier type lines are much longer in delay time than is typical for digital delay lines. A maximum limit, at this time, is about 40 milliseconds.

NRZ CIRCUITS

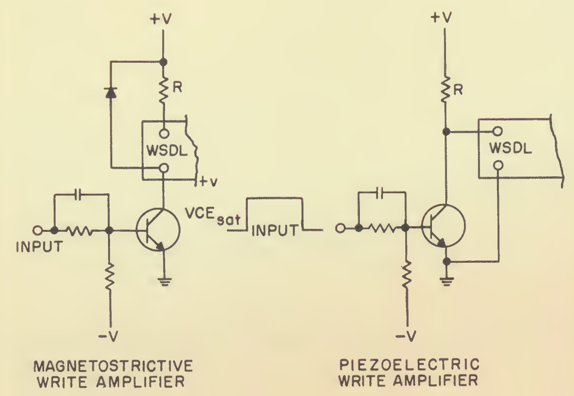


Fig. 13

WRITE AMPLIFIER Two simple drive circuits utilized as write amplifiers for Wire Sonic Delay Lines.

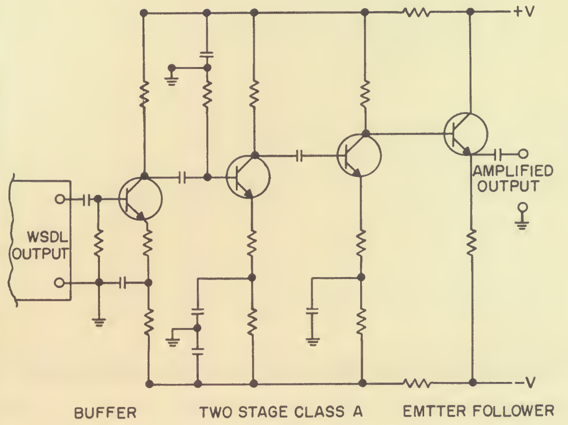


Fig. 14

READ AMPLIFIER The read amplifier is a wide band Class A amplifier. The band width (3 db) is normally 0.1 to 3 f_o, where f_o is the center frequency of the wire sonic delay line.

DETECTOR FLIP FLOP

Basic detector. The threshold levels are determined by the base emitter drop, V_{BE}, when the transistor is on, and diode drop when the transistor is off. The incoming signal turns the transistor off and on.

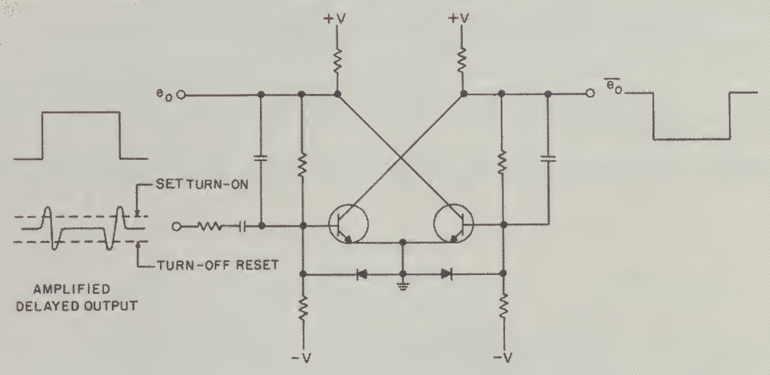


Fig. 15

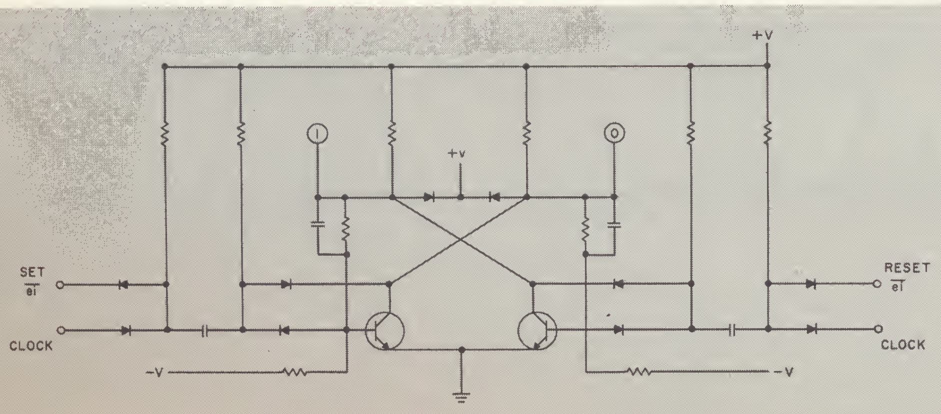


Fig. 16

TIMING FLIP FLOP

Any general purpose flip flop will suffice. Such a flip flop is illustrated.

RZ CIRCUITS

WRITE AND READ AMPLIFIER

The write and read amplifiers described for the NRZ technique are useable for RZ recording.

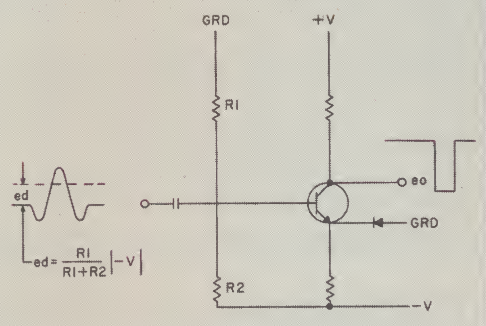


Fig. 17

DETECTOR
(Simple Threshold Type)

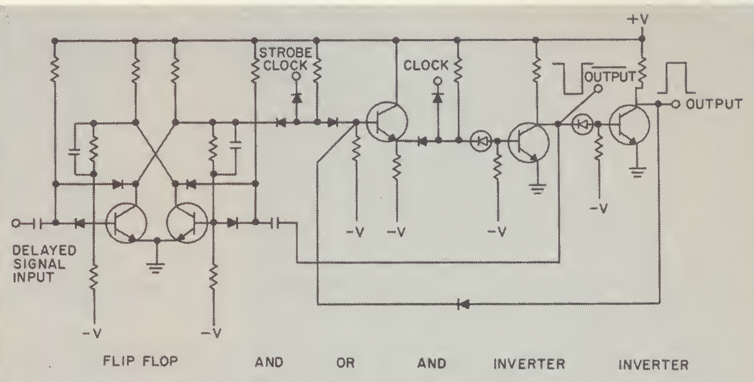


Fig. 18

CLOCKING CIRCUITRY

BIPOLAR CIRCUITS

WRITE AMPLIFIERS

The Bipolar write amplifier for the magnetostrictive transducer is merely the dual of that used for the RZ and NRZ techniques. The piezoelectric transducer is effectively a single terminal device, since one terminal, the delay medium, is at signal ground. AC coupling is not readily obtained and normally direct coupling is preferred.

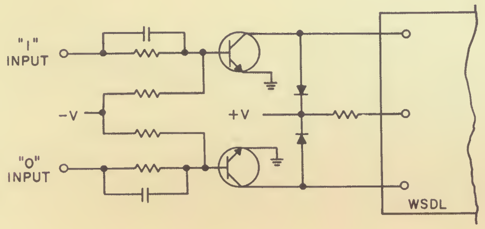


Fig. 19

MAGNETOSTRICTIVE WRITE AMPLIFIER

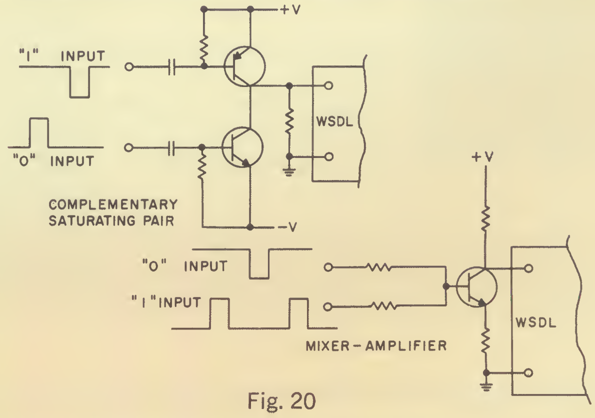


Fig. 20

PIEZOELECTRIC WRITE AMPLIFIERS
(Two Types are Illustrated)

READ AMPLIFIER

The same read amplifier utilized in the NRZ mode is applicable; however, the band width can be reduced on the low frequency end, if desirable.

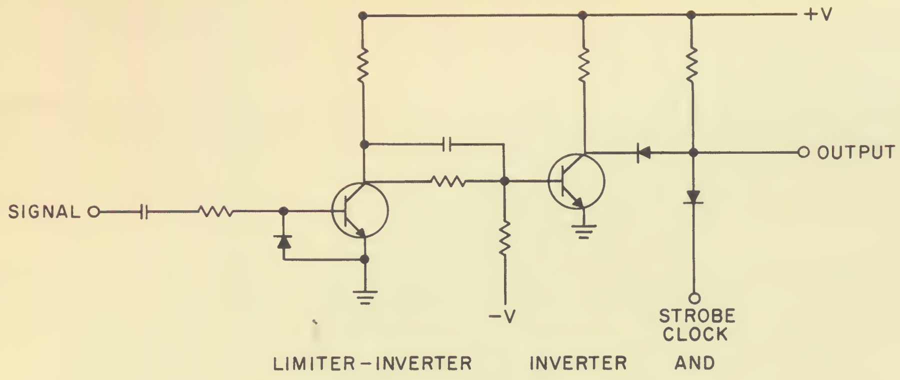
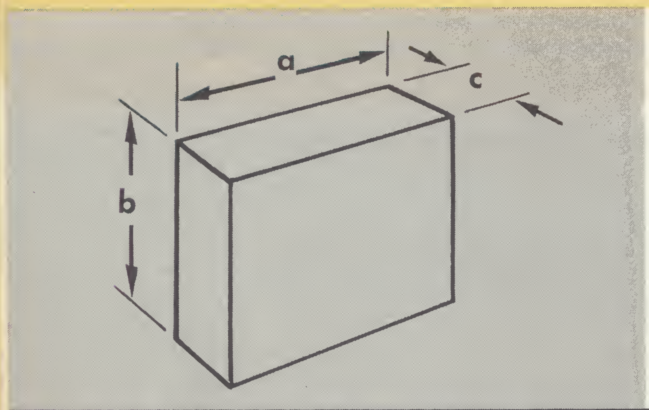


Fig. 21

DETECTOR

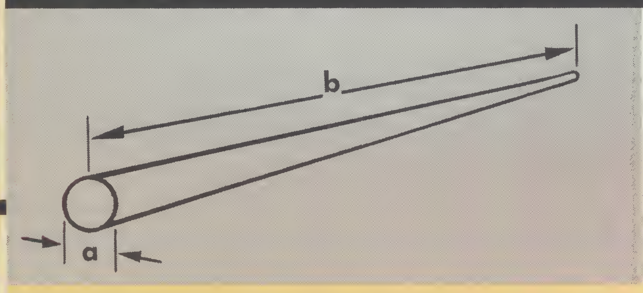
The detector for the Bipolar technique.

TYPICAL DIMENSIONS



RECTANGULAR TYPE

SIZE a b c	DELAY TIME
5 x 1 x 0.5	1 — 20 μsec.
5.5 x 4.5 x 0.7	20 — 2,000 μsec.
9 x 9 x 0.7	2,000 — 8,000 μsec.
12 x 12 x 0.7	8,000 — 12,000 μsec.
15 x 15 x 1.0	12,000 — 20,000 μsec.

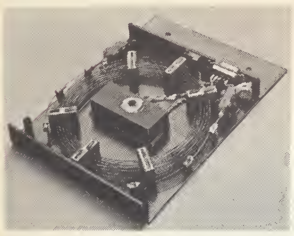


TUBULAR TYPE (Fixed Delays Only)

Diameter 3/16 inch Max. (a)
Length = 6″ + 0.1″/μsec. (b)
(incl. terminals)

(One terminal at each end with case grounded as common)

CUSTOM DESIGN SERVICE



Custom shapes and sizes are available to meet specific applications. Input/output circuitry can be accommodated inside the delay line case if desired. Where required, the delay lines are hermetically sealed.

With the increasing acceptance of delay lines by engineers to be used as storage elements in digital systems and in signal processing applications, we offer a further service for complete memory packages, including all circuitry in encapsulated or printed wiring form.

CONCLUSION

COMPARISON OF TRANSDUCERS AND DELAY LINES

As we have seen by the information given, each type of transducer and each type of mode has its own characteristics. Briefly, a comparison shows that due to the fact the magnetostrictive transducer is electromechanically coupled to the transmission media, it can be slid up and down, thus providing a delay adjustment capability.

This adjustment capability is off set however, by the many advantages afforded users by physical coupling of the piezoelectric transducer. These advantages are: *less attenuation* — 1 milli-second fixed delay at 1 MC PRF is only 30-35 db; *higher frequency response* — operating information rates up to 2.5 MC RZ, 5 MC NRZ; *more rugged* — up to 30 G's vibration 20-2,000 cps; *greater dynamic range* — 50 to 60 db. The combined type Wire Sonic Delay Lines include advantages of both the magnetostrictive and piezoelectric transducers.

COMPARISON OF RECORDING TECHNIQUES

PRR
Unlike the NRZ and RZ, which operate better the higher their frequency response over that required, the Bipolar must have a response tuned to the required i.e. — a specified pulse width for proper operation.
NRZ is the mode of highest PRR. Both RZ and Bipolar recording are only one-half that of NRZ.

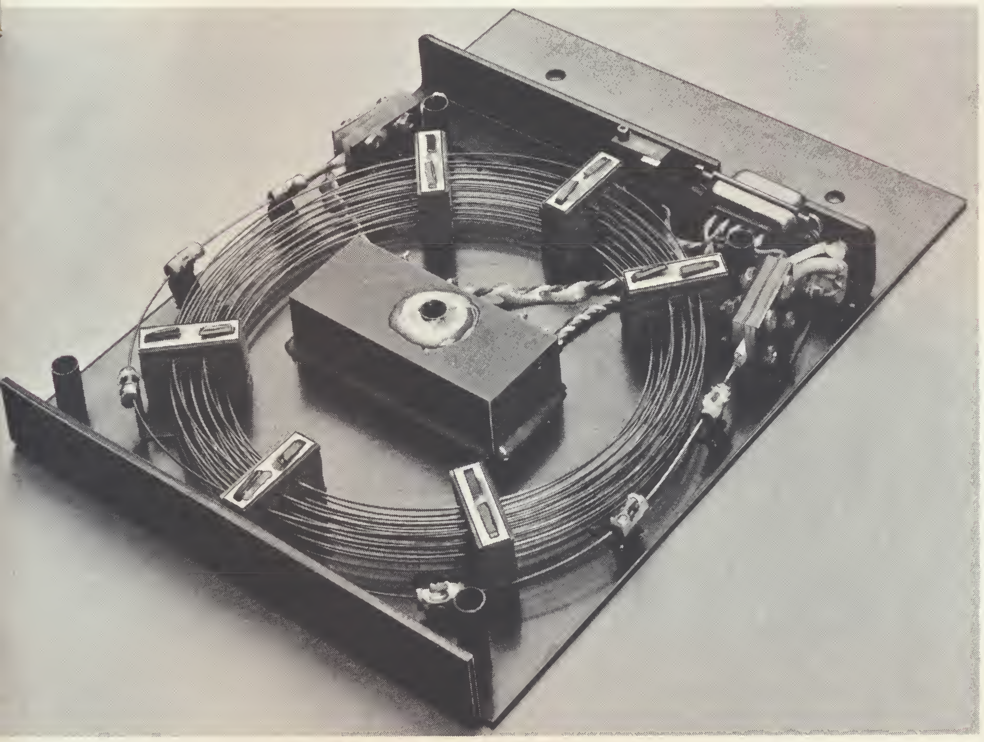
SIGNAL-TO-NOISE
NRZ has only one-half the signal amplitude of the RZ and Bipolar; it must therefore have one-half the noise. Thus, the NRZ mode must be operated in a more controlled environment. The Bipolar is capable of operating in the more stringent environment.

DELAY DRIFT
RZ has over twice the allowable drift tolerance as the NRZ and Bipolar.

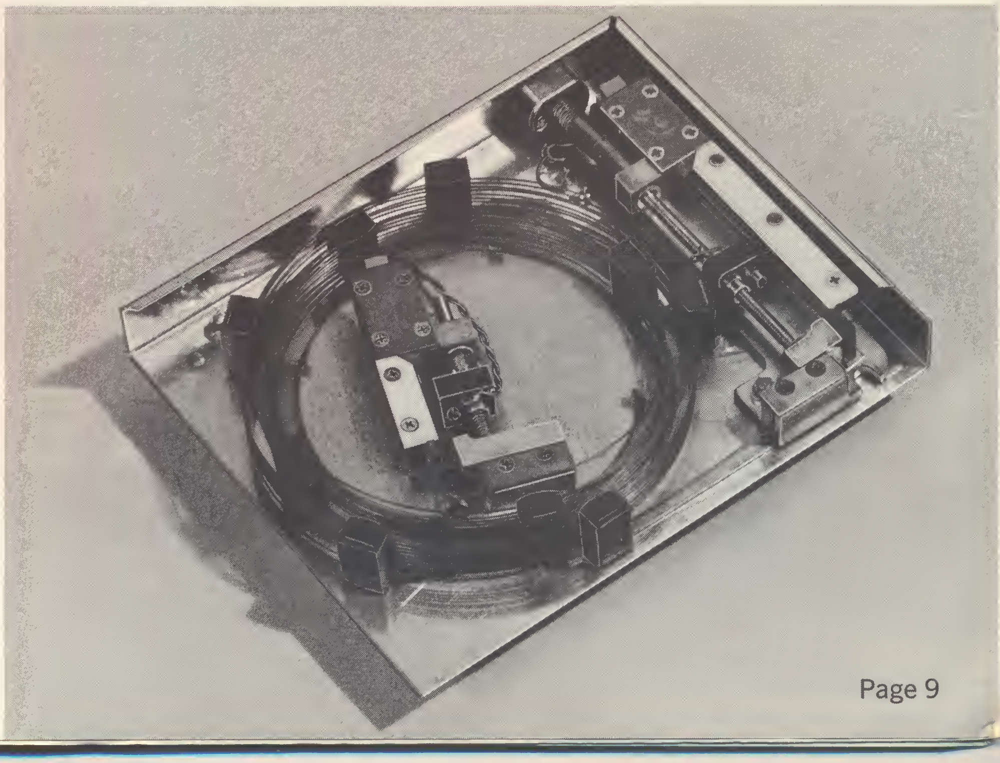
LARGEST SELECTION OF STANDARD AND CUSTOM LONGITUDINAL, TORSIONAL MAGNETOSTRICTIVE AND PIEZOELECTRIC DELAY LINES

GENERAL ELECTRIC'S ADVANCED DESIGN AND CONSTRUCTION PROVIDE

- Higher frequency response — up to 2.5 mc RZ, 5 mc NRZ
- More Rugged — physical coupling of piezoelectric transducer increases resistance to shock and vibration (up to 30 G's, 20-2,000 cps, operating)
- Less attenuation — only 30-50 db for a typical 1 ms fixed delay at 1 mc PRF
- High dynamic range available — not saturated by large input amplitudes

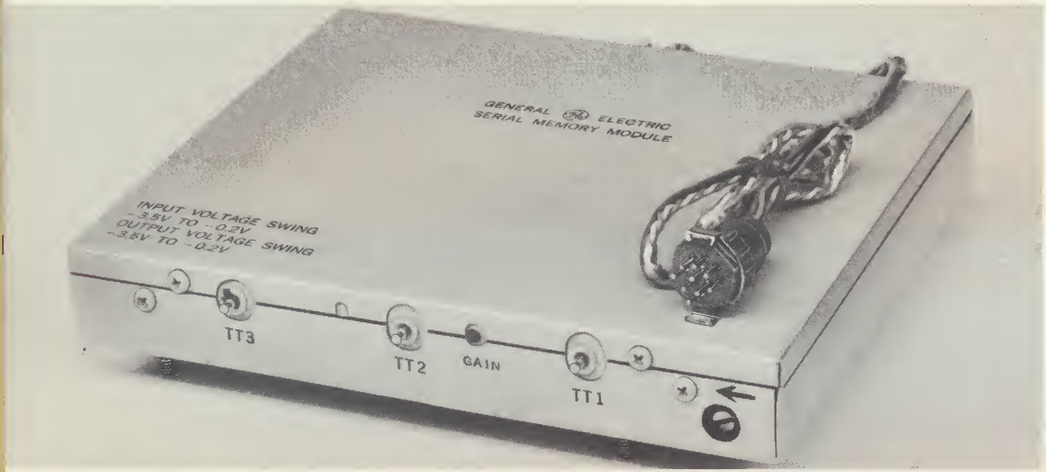


2,000 microsecond delay line with direct drive piezoelectric torsional transducers. Input-output circuitry in encapsulated form mounted within case.

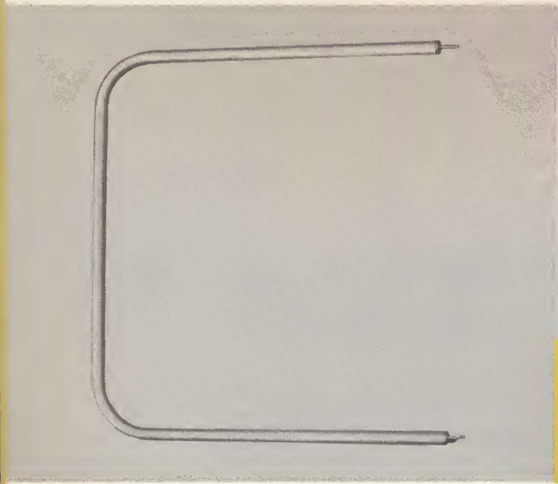


2,000 microsecond torsional delay line with magnetostrictive transducers, using mode converters. Adjustable output.

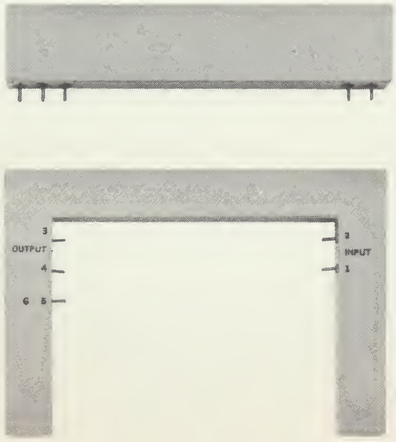
LARGEST SELECTION OF STANDARD AND CUSTOM LONGITUDINAL, TORSIONAL MAGNETOSTRICTIVE AND PIEZOELECTRIC DELAY LINES



250 microsecond magnetostrictive delay line with input-output circuitry packaged within case.

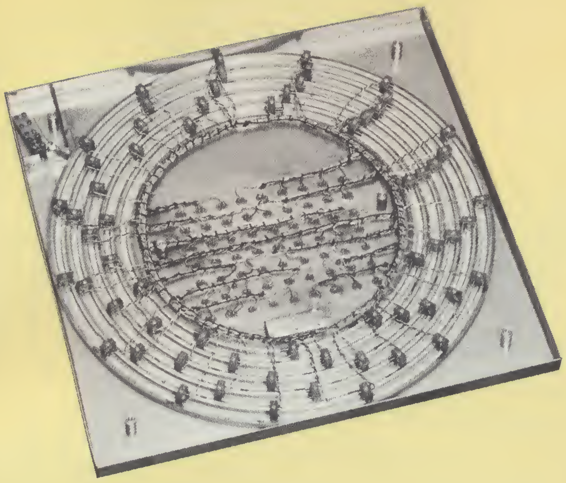


30 and 50 microsecond direct drive piezoelectric torsional delay lines. Maximum volume utilization.



425 microsecond delay line with piezoelectric input transducer and magnetostrictive output transducers.

Magnetostrictive delay lines for print wire board mounting.



MULTIPLE TAP DELAY LINES

The multiple tap wire sonic delay line is filling an increasingly important role in signal processing applications in radar, sonar, and communications electronic equipment. It is useful for the temporary storage of target information, for comparison with information subsequently obtained. The devices can be used in beam forming and steering applications. They are also useful for correlation techniques, such as are used in secure communications methods.

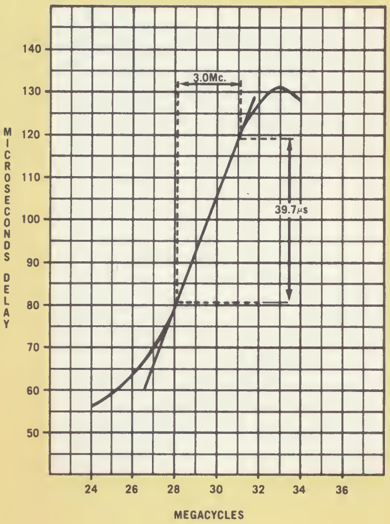
These applications may require 100% bandwidths, although they are normally narrow band, and the delay line is tuned to a specific center frequency, giving it band pass characteristics, and providing relatively low voltage insertion loss.

Taps are fixed or can be furnished with some adjustment internally (removal of the case cover). Minimum spacing between taps is 1-2 microseconds. Externally adjustable taps can be provided for special design considerations and in limited number.

General Electric is in position to furnish units with delays of up to 50 milliseconds and with up to 100 taps.

Long experience in building multiple tap delay lines enables General Electric to design these delay lines with very high signal-to-noise ratios.

TYPICAL RESPONSE CURVE FOR DISPERSIVE DELAY LINE



NEW-HIGH FREQUENCY DISPERSIVE DELAY LINES

These newly developed lines for use in pulse compression systems feature controlled dispersion. They utilize propagation of the longitudinal mode in wires or thin strips, and are designed to replace the narrow band matched filter systems now in use. They offer substantial improvement in size and weight, and in the difficulties of alignment and maintenance of the filter system.

The bandwidth is about 10% of the center frequency, and a compressed pulse has a duration equal to the reciprocal of the bandwidth. Thus, a delay line which must provide a compressed pulse width of 0.5 microsecond must have a bandwidth of 2 megacycles, and a center frequency of 20 megacycles. If this line must provide a compression ratio of 100, for example, a linear variation in delay of 50 microseconds will be required, and since the useful linear dispersion is about equal to the low frequency delay (5 microseconds per inch of travel), a delay line approximately 10 inches long is necessary. The center frequency is a function of line geometry and a desired frequency can generally be attained within less than 2%. Once the delay line is built, this center frequency will not vary.

Delay lines are available with up to 60 megacycle center frequency and 6 megacycle bandwidth. The graph shows the performance of a 30 megacycle center frequency delay line of 3.0 megacycle linear bandwidth, and 39.7 microseconds linear dispersion for a pulse compression ratio of 120. The case size of this delay line is 10" x 2" x ½".

GENERAL SPECIFICATIONS:

Operating Frequency	100 KC up to 60 MC, currently
Bandwidth	10% of operating frequency
Compression Ratios	100:1 normal limit
Linearity	1% within the 10% bandwidth
Temperature Sensitivity	.03%/C° absolute maximum
Shock and Vibration	MIL-S-901B, MIL-E-16400
Insertion Loss	40db maximum

WIDTH SHEAR STRIP LINES

These devices are new developments which show promise of permitting operation in the 5 to 20 MC region. The delay line is essentially a thin strip of nickel-iron alloy metal whose width is 100 times or more than the thickness. Piezoelectric transducers at either end are driven in the width shear mode, and the delay line is capable of successfully transmitting 5-20 MC carrier or digital information.

In certain applications, these delay lines offer several advantages over glass or quartz sonic delay lines:

1. Lower cost, particularly in the longer delays.
2. Lower temperature coefficient of delay.
3. Lower input capacitance for a comparable insertion loss.
4. Smaller volume and less weight.

Proposal requests are solicited at this time in the 10 to 500 μ sec. range.

WIRE SONIC DELAY LINE SPECIFICATION QUESTIONNAIRE

(To be completed for technical feasibility or quotation requests)

TOTAL DELAY .... μsec.

DELAY TOLERANCE (for fixed outputs) ±... μsec.

DELAY ADJUSTMENT (for variable outputs) ± .... μsec.

TAPS (if any) at .... μsec.

ALLOWABLE DELAY DRIFT (all reasons) .... μsec.

INPUT CHARACTERISTICS

DIGITAL DELAY LINES

Pulse Repetition Rate ....Maximum
Pulse Width .... μsec. at 50% pts.
Rise & Fall Time .... μsec. at 10 to 90% pts.
Voltage Amplitude (piezo. inputs) ....volts
Current Amplitude (magnet. inputs) ....ma.
Source Impedance ....ohms
Recording Mode ☐ RZ ☐ NRZ ☐ Bipolar

CARRIER DELAY LINES

Center Frequency ....Maximum
Bandwidth ....Maximum
Voltage Amplitude (piezo. inputs) ....volts
Current Amplitude (magnet. inputs) ....ma.
Source Impedance ....ohms

OUTPUT CHARACTERISTICS

Pulse Width .... μsec at 50% pts.

Voltage Amplitude ....volts minimum

Load Impedance ....ohms

Signal-to-Noise Ratio .... (Single Pulse)

.... (Random Pulse Pattern)

Other Requirements ....

....

....

....

....

ENVIRONMENTAL REQUIREMENTS

OPERATING

Temperature ....to ....°C

Vibration (Max.) ....G's, from ....

to ....cps

Shock (Max.) ....G's, for ....msec.

Other (Humidity, Altitude, etc.) ....

....

OPERATING

Temperature ....to ....°C

Vibration (Max.) ....G's, from ....

to ....cps

Shock (Max.) ....G's, for ....msec.

Other (Humidity, Altitude, etc.) ....

....

MECHANICAL REQUIREMENTS

Maximum Dimensions ....inches

Maximum Weight ....oz.

Type of Terminals ....

Is sealed case required? ☐ YES ☐ NO

INPUT/OUTPUT CIRCUITRY

☐ To be furnished by General Electric

☐ Mounted Inside Case

☐ Mounted Outside Case

Quantities Required ....

Delivery Required ....

Other Information Needed ....

....

....

....

Name .... Title ....

Company .... Dept. ....

Address ....

City .... State ....

Date ....

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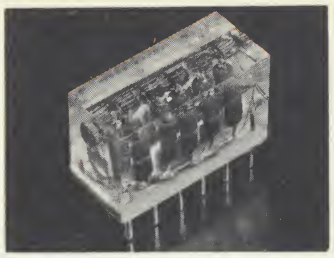
1811 LEMOYNE AVENUE

ELECTRICALLY VARIABLE DELAY LINES

LUMPED CONSTANT



Electrically Variable Delay Line, a General Electric product offering a unique approach to pulse positioning and phase control, features the advantage of controlling delay by electrical rather than mechanical means. This device effects variation in delay through the application of direct current and voltage bias on a control windings. In addition to these static control techniques, alternating currents up to 100 kc may also be used to achieve dynamic control or modulation.

Electrically Variable Delay Lines provide a new method for the solution of problems in transmission time control, pulse control and shaping, high frequency phase control, pulse time modulation, and phase or frequency modulation.

Designed and built for either carrier or pulse type applications, these Electrically Variable Delay Lines can be produced within a wide range of operating characteristics. They are highly adaptable to transistorized circuitry and will withstand extreme humidity, shock, and vibration.

Inquiries are invited regarding delay lines for specific application, tailored to customers' needs in such equipment as radar, computers, and mobile communications.

The delay line is composed of series connected inductors, with voltage variable capacitors in shunt across the line (typical pi section L-C network). The inductors have a second winding wound around them, which is then connected to an external current source. Increasing current through this control winding decreases the network's impedance and shortens the delay time.

The voltage variable capacitors have an external voltage bias supply connected across them. Increasing this voltage increases the network's impedance and shortens the delay time. Increasing both voltage and current simultaneously will permit the delay line to be shortened at approximately constant impedance. The effect is non linear, however, requiring compensation in the control circuitry *if* linearity is a requirement. We shall be glad to furnish circuit suggestions to accomplish this linearity, if they should be needed or desired by users.

The current supply is typically in the 200 to 400 milliampere range, depending on delay line design, at a low voltage (4 to 10 volts). The voltage supply is typically 0 to 70 volts with a current requirement in the low microampere range.

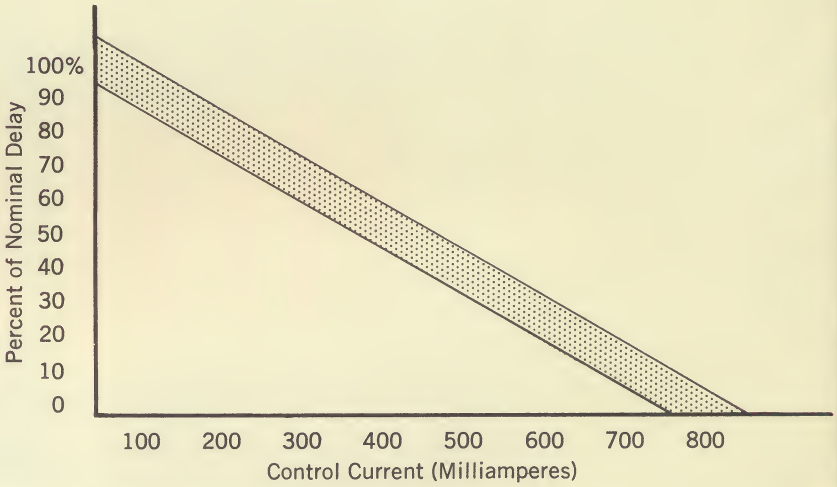
Using either the current or voltage supply independently, the delay time can be reduced to about 40 percent of the unit's nominal delay. If both supplies are used, the delay time can be reduced to about 15% of nominal delay, or a 6:1 or 7:1 ratio. The current bias may be in either direction, but the voltage bias must be positive in respect to ground. For minimum distortion, the input signal should be less than one volt, peak to peak.

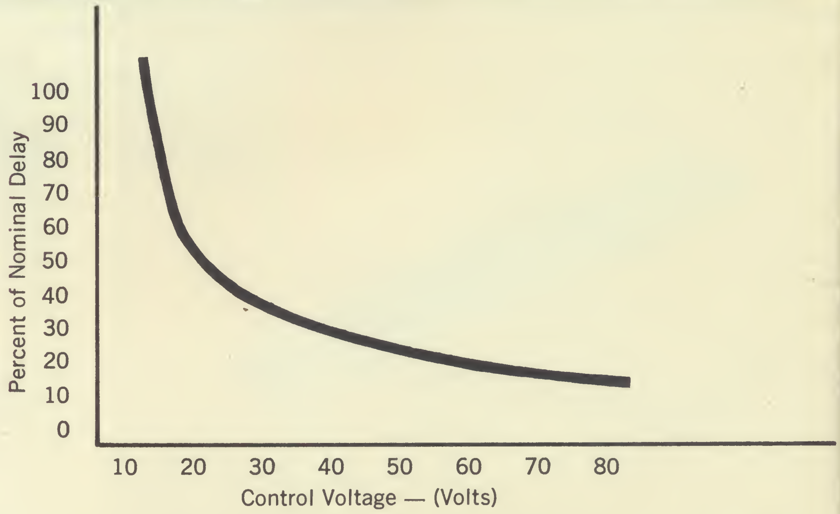
GENERAL SPECIFICATIONS

Delay-Bandwidth Product	10 mc μsec. Max.
Maximum/Minimum Delay Ratio	7:1 Max.
Delay-to-Rise Time Ratio	20:1 Max.
Characteristic Impedance	any value from 50 to 50,000 ohms. Some restrictions when operating at extreme range of other specifications

TYPICAL CURRENT/VOLTAGE CURVES

Delay variation requires two separate sources; one current source (upper curve) and one voltage source (bottom curve). Both are low power circuits. We will supply associated modulation circuitry.





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GENERAL ELECTRIC

SPECIALTY DEVICES OPERATION
SYRACUSE, NEW YORK

JUST RELEASED —

It is a pleasure to send you one of the copies from our first run of what we believe to be the industry's most complete technical bulletin on wire sonic delay lines.

I would appreciate your comments after you have had an opportunity to review the attached literature.

T. F. MacCoun
Manager Marketing
Specialty Devices Operation

Gentlemen:

☐ The information on wire sonic delay lines is adequate.

☐ I require additional information:

☐ Prices ☐ Delivery ☐ other __________

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2. My application is __________

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SDO-64-1

T. M. Egbert, Jr.

FOR RELEASE MONDAY, MARCH 16, 1964

SYRACUSE, N. Y., Mar. 16--The General Electric Company today announced the signing of an agreement with Andersen Laboratories, Inc., West Hartford, Conn., in which Andersen has been granted a license relating to sonic delay lines, developed by General Electric's Specialty Devices Operation, here.

The agreement licenses technical information and know-how pertaining to magnetostrictive, piezoelectric and dispersive delay lines, and also provides for the transfer to Andersen of certain manufacturing tooling.

General Electric pioneered in the development of sonic delay lines incorporating piezoelectric transducers and high-frequency dispersive lines. Andersen Laboratories has been a leader in the ultrasonic delay line industry since 1949 and brings an extensive background to the design and production of these delay lines.

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